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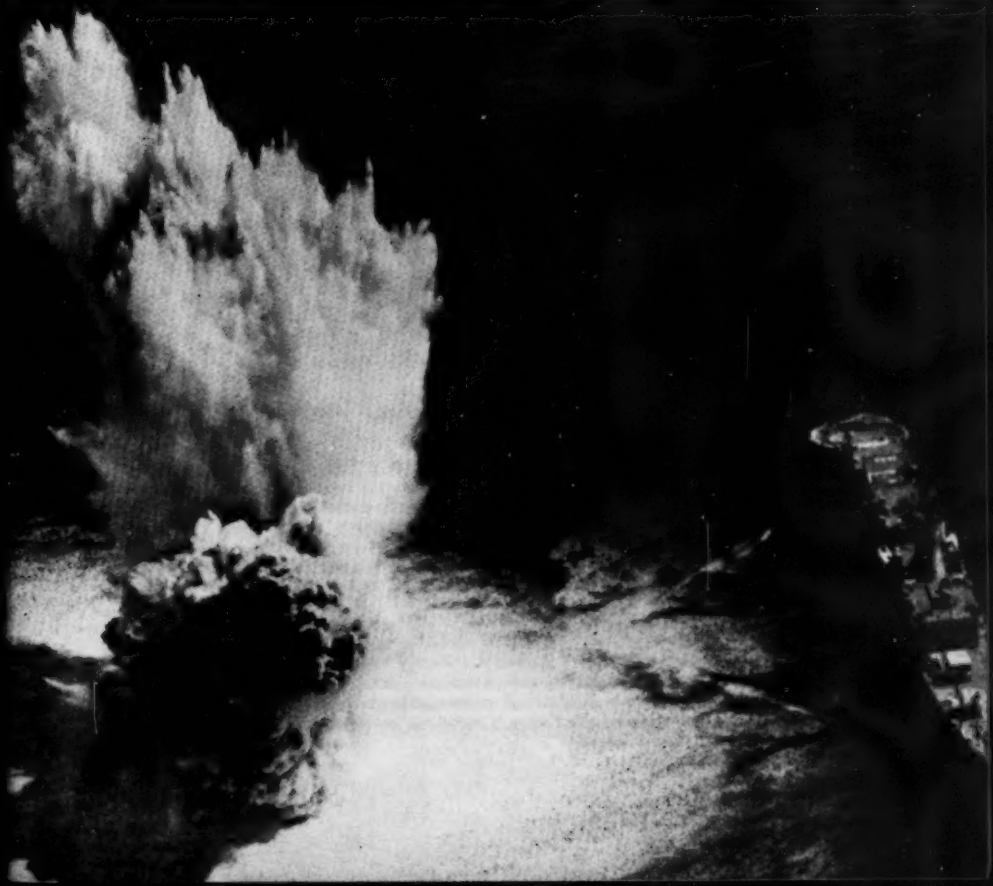
NAVAL RESEARCH

REVIEWS

APRIL 1974



PROFILES IN SCIENCE

Dr. Ruth D. Turner

Dr. Ruth D. Turner, who is the Alexander Agassiz Fellow in Zoology and Oceanography at Harvard, has been an Office of Naval Research contractor for the last twelve years. Much of her research has been with marine boring and fouling organisms, particularly mollusks. These are of great concern to the Navy in the maintenance of water front structures and ships.

In controling any pest it is essential to know its life history, and to ascertain the weak-link which usually proves to be the point of control. Studies done by Dr. Turner with ONR support have shown that for marine fouling bivalves the most critical period is the time of settlement and metamorphosis of the larve.

While collecting and observing teredinids, a type of marine borer, in their habitat, Dr. Turner had the idea that many tropical trees have built-in resistance to borers. She is working with Dr. John Bultman of the Naval Research Laboratory analyzing the effects of chemicals found in naturally resistant tropical woods on the metamorphosing larve; the results may change the established methods of protecting wood for use in the marine environment.

Among her many publications Dr. Turner is noted for her reference work "A Survey and Illustrated Catalogue of the Teredinidae."

The Oceanic Carbon Cycle

W. G. Deuser

Woods Hole Oceanographic Institution

The carbon cycle is fundamental to one of the major chemical systems in the ocean environment, the carbon dioxide system. This system, in addition to containing the element that forms the framework of all organic molecules, also plays a major role in a number of chemical processes in the marine environment which constitute the basis of several operational problems for the Navy. Specifically, problems of corrosion in aerobic and anaerobic environments; characteristics of the ocean bottom which might influence the implantation of systems; factors which enhance or inhibit biological fouling; and the effects of organic matter on biological populations and pollution, are all related to the carbon dioxide system in the ocean. The reason for this is that the carbon dioxide system plays a strong role in maintaining a relatively constant pH in seawater; it participates in numerous chemical equilibria involving both major and minor elements in seawater; and in many cases it significantly characterizes the ocean bottom, through the deposition of debris resulting from the degradation or organic matter. The Navy must understand this chemical cycle and the inseparable consideration of carbon-containing molecules in the marine environment to effectively combat the operational problems which are being met as a result of this characteristic of the ocean. The Office of Naval Research is sponsoring Dr. Deuser's research to gain an understanding of the relationships between the many varied phases of carbon in the ocean, their relation to other phases in the ocean environment, and the source, fate and regeneration of carbon phases. This research will provide the basic knowledge necessary for the Navy to better contend in the future with environmental problems such as those indicated previously.

Chemistry of the Ocean

The world's oceans and seas are not only a vast physical system, but also a highly complex chemical one. While the composition of sea water is surprisingly uniform from place to place, this apparent simplicity is the result of a complex network of chemical and physical

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*Dr. Werner G. Deuser is an Associate Scientist in the Department of Chemistry of the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Dr. Deuser has been associated with ONR since 1968, beginning as a co-principal investigator in conducting research associated with the organic chemistry of seawater and is now a principal investigator, internationally recognized for his investigations on carbon isotopes in the marine environment.

processes, many of which are still very poorly understood. We now know that every naturally occurring element, and many man-made isotopes as well, are present in sea water. We also know that very few, if any, of the elements pass through the ocean without interacting with others along the way. Every atom now in the ocean entered it long after the ocean formed and will leave it sooner or later. It may re-enter the ocean thereafter, driven by the forces which shape the surface of the earth. The time which each element spends in the ocean, on the average, depends on the type of interactions which it undergoes during its stay. Some elements, such as aluminum, interact strongly in sea water and are removed from it very rapidly. The average time which an aluminum atom spends in the ocean in any form is less than 100 years—not long on a geological time scale. Other elements such as, sodium, the major metal in sea water, make near-perfect solutes by themselves, interact very little with sea water, and may, on the average, spend millions to hundreds of millions of years in the ocean. In general, it may be said that the more depleted an element is in sea water in comparison to its average abundance in the earth's crust, the shorter its residence time in the ocean.

Carbon in the Ocean

Carbon may not fit into any simplistic scheme, such as the one just outlined. Carbon is fairly abundant in the ocean (28 mg per liter) and forms more chemical compounds than all other elements combined; it is the basic substance of living things and is in constant interchange among continent, ocean, sediment and atmosphere and between living and dead matter, organic and inorganic forms.

Because of the great complexity of carbon chemistry we are far from understanding the pathways of carbon through the ocean and its effect on the chemistry of the ocean in general. Through the enormous variety of organic compounds, carbon exerts an influence on the marine chemistry of other elements which contribute in making the chemical characteristics of the ocean what they are. Heavy metals, for example, are incorporated in organic complexes and absorbed on organic particles. The very formation of organic matter in the tissues of plants or animals involves the uptake of many elements from the aqueous medium into discrete packages which may become enriched in those elements tenfold, a thousandfold, even a millionfold in some reported instances. Both during the life and after the death of the organisms, dissolved and particulate organic and inorganic constituents are produced that continue to redistribute chemicals in the ocean through continued uptake from the water or by decomposing,

settling and being carried along with the currents. The understanding of the behavior of metals and many other substances, including man-made ones, is thus intimately linked to an understanding of the pathways of carbon.

Questions to be Answered

Marine biologists have given us a reasonably good idea of the quantities of primary organic matter produced through photosynthesis in the oceans per day or year and of the regional variations of that production. Photosynthetic production is restricted to the upper two hundred meters or so, where sun light is able to penetrate. It is predominantly carried out by tiny single-cell algae which in turn sustain almost all animal life in the ocean. The greater part of the organic matter formed near the surface is also utilized and decomposed there and smaller and smaller fractions of it reach the deeper waters. Knowing just how much organic matter reaches a certain depth and how much of it is oxidized there before descending to even greater depths is important for several reasons. Biologists would like to know more about the metabolic rates in the deep sea; for a given population of organisms the metabolic rate is dependent on its supply of energy in the form of organic matter which it can utilize. Chemists would like to know where organic carbon is broken down, what the resulting products are and what chemical forms the remainder has—not only for the sake of finding out more about the makeup and fate of organic matter in the ocean, but also because of the implications for the behavior and fate of those substances which pass through the ocean in association with organic matter. Finally, in today's world these questions have a direct bearing on the capacity of the ocean to accept and digest the great variety of organic and inorganic wastes of civilization.

Less than 1% of the living organic matter on earth resides in the ocean; yet, dead organic matter in sea water exceeds the amount of living organic matter both on land and in the sea. These two facts suggest that it must have taken a long time for the dissolved organic matter to accumulate. How long? Radiocarbon measurements suggest a few thousand years—but that is only an average age. No doubt some of the organic matter is much younger and some of it must be much older. Much of it is not yet identified chemically, nor are we sure of its origin or eventual fate. The concentration of dead organic matter is upward of about one-half of a milligram per liter of sea water, a level higher than that of all but 10 of the elements. How much of the chemistry of these elements does this organic matter

control? Is the movement of these elements through the ocean directly tied to the flux of certain organic compounds through the ocean? How important are exchange reactions between the water and the sediments? We do not know the answers with any degree of certainty.

I can here only pose some of the many questions about the complex behavior of carbon in the ocean and about its importance for the chemistry of the ocean in general. One way of getting some of the answers is to study the isotopic makeup of the different forms of carbon in the sea.

Stable Isotopes of the Carbon in the Sea

Carbon has two stable isotopes, C^{12} and C^{13}; the latter has one additional neutron in its atomic nucleus. This difference in mass between the two isotopes (8%) is sufficiently large to cause significant differences in the chemical and physical behavior of the two isotopes and of compounds, especially those of low molecular weight, into which they enter. The relative abundance of the two isotopes in natural substances may, therefore, vary by as much as 10%. For example, methane forming in marshes or anaerobic sediments typically contains one C^{13} atom for every 95 C^{12} atoms, whereas the calcium carbonate formed by marine organisms such as clams, corals, or foraminifera, typically contains one C^{13} atom for every 89 C^{12} atoms. Modern analytical instruments enable us to measure much smaller differences in carbon isotope ratios. Most mass spectrometers designed for that purpose easily distinguish differences in the C^{13}/C^{12} ratio of two samples as small as 0.01% or roughly one thousandth of the range of natural variations. As a matter of convenience the measurements are reported as a difference δ from a standard and are expressed as parts per thousand.

$$\delta C^{13}\ (\%) = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1{,}000$$

where R is the ratio C^{13}/C^{12}. The standard commonly referred to has a C^{13}/C^{12} ratio close to that of inorganic carbon in the ocean. Positive values thus signify enrichment in C^{13} relative to the standard, and negative values signify depletion.

The process which produces a difference in isotope ratio between two substances is called isotope fractionation. Differences in bond strengths lead to an uneven distribution or isotopic molecules between

two different chemical compounds or between two different states of the same compound. Given sufficient time, the distribution will attain an equilibrium state in which case we speak of equilibrium fractionation. However, many processes in nature do not achieve equilibrium, and differences, sometimes in excess of equilibrium fractionations, may be produced by differences in reaction rates, diffusion rates, evaporation rates and other processes which at times may involve several reinforcing stages, none of which has a chance of attaining equilibrium. For example, the physical and chemical steps which lead to the conversion of inorganic carbon to organic carbon during photosynthesis, and even more so, the bacterially mediated formation of methane during the decomposition of organic matter, involve some of the largest natural isotope fractionations known. The reasons for these fractionations, which may lead to depletions in C^{13} of 6% in the case of methane formation, are still poorly understood.

Investigations of the Marine Carbon Cycles

Over the past several decades equilibrium and non-equilibrium isotope fractionations have been studied in a great variety of chemical and biological systems. More recently the results of those studies have been and are being applied to unraveling the origin and history of naturally labeled compounds. A good example is the unequivocal recognition that petroleum forms from organic starting materials. Petroleum has the low C^{13} content characteristic of organic matter. Because the isotope fractionation which accompanies photosynthetic carbon fixation is so large, organic matter in general retains a low C^{13} content even though minor changes occur in secondary modifications and utilizations by organisms of the primary organic carbon. This characteristically low C^{13} content of organic matter also aids in our studies of the marine carbon cycle.

The normal range of δC^{13} for a number of marine carbon reservoirs is shown in Table 1. A reservoir refers to specific items such as plants or sediments. Considerable differences exist; thus, carbon taken from any of these reservoirs bears a natural label in the value of its C^{13}/C^{12} ratio. For any particular part of the ocean the ranges in δC^{13} of the different carbon forms are narrower than those in the table.

Let us consider one aspect of the carbon cycle. The removal of carbon which is depleted in C^{13} from the inorganic carbon pool (ΣCO_2 or total CO_2) during photosynthesis leaves the remaining inorganic carbon enriched in C^{13}. Although the amount of carbon removed that way is much smaller than that remaining, both the changes in ΣCO_2 and δC^{13} can be measured. With increasing depth in the ocean

Table 1
Common Ranges of δC^{13}* in Marine Carbon Reservoirs

Reservoir	δC^{13} (%)
Atmospheric CO_2	- 7 to - 9
Dissolved inorganic carbon	- 1 to + 2
Carbonate skeletons of plants and animals	- 2 to + 5
Plants and animals, organic C	-15 to -30
Dissolved organic carbon	-20 to -33 (?)
Particulate organic carbon	-17 to -30 (?)
Sedimentary organic carbon	-18 to -25
Methane in anoxic sediments and waters	-60 to -70

* For definition see text

the removal of inorganic carbon through photosynthesis loses importance and the return of oxidized organic carbon gains in importance. Again, the changes can be measured, but only the net effect of removal minus return, where both occur. At depths where photosynthesis can no longer take place only oxidation remains. Measuring only the variation of the inorganic-carbon concentration gives us no information on the nature of the organic matter involved. Measuring the changes in makeup of the organic matter itself still poses difficult analytical problems. An easier, though indirect, way of getting at the problem is to determine the isotopic composition of the carbon removed from or added to the inorganic carbon pool at any depth. That composition can be calculated from the changes of δC^{13} and ΣCO_2 with depth. If δC^{13} of any added carbon dioxide changes with depth, as recent results indicate, this is a sure indication of a change in the type of organic matter oxidized at different depths. From comparisons with δC^{13} values of different groups of organic compounds the sequence of oxidation can then be unraveled. Selective oxidation in turn should change the composition of the remaining dissolved and particulate organic matter, and with improved analytical methods we hope to be able to determine the nature and extent of those changes.

In very deep water ΣCO_2 may be increased also through solution of carbonate particles which rain down from the surface waters. That

addition may be assessed since the carbonate has a δC^{13} very different from that of organic matter. Carbonate solution complicates the investigation of changes in the oxidation of organic matter, however, since it introduces an additional unknown. Fortunately, this introduction can be neglected in the upper two or three kilometers of the ocean where most oxidation takes place, since the water there is saturated in calcium carbonate. It is our hope that the major trends in oxidation can be detected in the near-surface waters and that knowledge of them will aid in the more complex study of the deep water. Once we know the relative amounts and gross characteristics of organic matter oxidized at different depths and in different parts of the ocean we can, from the primary production rates, derive turnover rates. To do that we must assume, however, that the chemical make-up of the ocean does not significantly change over time spans comparable to the turnover times—and that, of course, is the subject of other intense investigations at the present time supported by the Chemical Oceanography Program of the Office of Naval Research.

A final point needs to be mentioned. Much of our knowledge on the rates of large-scale circulation and the turnover of water masses has been obtained from radiocarbon measurements on the ΣCO_2 in different parts of the ocean. "Ages" of water masses calculated from those measurements have in the past been based on the assumption that a parcel of water once having equilibrated at the surface of the ocean with the atmosphere (the source of radiocarbon) and having left the surface could not gain additional radiocarbon, and lose it only through radioactive decay. As we enlarge our understanding of the transport and oxidation rates of organic matter, which contains radiocarbon, we will be able to improve our assumptions or replace them by measured values and, thereby, refine our knowledge of the circulation of the ocean itself.

High Power Microwave Power Test Facility

Naval Research Laboratory (NRL) scientists have developed a 37 gigahertz (GHz) high power test capability at the Laboratory's Waldorf Microwave Space Research Facility for high power testing of satellite communication components and materials.

The test facility now has a 1 kilowatt K_a band power capability in the 36 through 38 gigahertz band. A small interior radiation chamber has been developed for antenna and materials evaluation at high radio frequency flux densities

(Continued on page 21)

Ocean Technology at NRL

J. P. Walsh*
Naval Research Laboratory

Introduction

Following recent trends in some industries, the Ocean Technology Division (OTD) at the Naval Research Laboratory (NRL) was created as a conglomerate of several other groups which previously had separate but related functions. The emphasis in each group or branch of the Division is on providing technology useful to the Navy in its current and future problems, and on basing this technology on a solid scientific foundation of research and at-sea experience. The Division is presently organized into the following groups:

Ocean Engineering Branch
Ocean Instrumentation Branch
Ocean Materials Criteria Branch
Applied Mechanics Branch
Shock & Vibration Information Center
Division Consultant Staff

The primary group that makes up OTD came from the former Mechanics and Sound Divisions. Both of these Divisions dated from the earliest days of NRL, some 50 years ago, and several of the current problems of interest can be traced in evolutionary fashion back through these years. A major impetus to some of this work was introduced by the pressing problems of World War II, and this work, in turn, generated subsequent rapid advances in technology. It is appropriate to note this latter work as background for the current capabilities and studies of the Division.

The past and present studies in the Division fall naturally into three areas, each of which will be discussed in the following pages with a little historical background for perspective: ocean engineering and ocean instrumentation, ocean materials criteria, and applied mechanics.

Ocean Engineering and Ocean Instrumentation

During the later 1950's and early 1960's, the Sonar Systems Branch of the Sound Division was engaged in the development of major sonar

*J. PAUL WALSH has been Superintendent of the Ocean Technology Division since 1969. His past experience includes weapon effect studies in Operation Crossroads (Bikini, 1946) and Operation Wigwam (1955), supervision of the shock design of reactor compartments on the first nuclear-powered submarines NAUTILUS and SEAWOLF.

systems for research and evaluation. The course of events eventually led to a requirement for acoustic measurements at very great depths in the ocean.

While conducting these measurements, the group developed strong capabilities in the packaging of equipment for deep submergence and in conducting remote-control experiments by means of telemetry over large cables. Special shipboard equipment-handling systems were developed, the largest towed body known to have been deployed from a ship (30 ft long, 8 ft wide, and 11 ft high) was successfully employed, and experimental equipment weighing up to 6000 lb was towed at depths as great as 16,000 feet.

The tragic loss of THRESHER (SSN395) on April 10, 1963, was a turning point for this group. Their deep-ocean instrumentation and towing capabilities were pressed into service in the search for the lost submarine. During this search period the Navy organized a Deep Submergence Review Group which recommended many actions to fill the technology gap in deep-submergence operation. With the successful location of the THRESHER hulk in 1964, it was time for change. The Ocean Sciences Division was formed, and the former Sonar Systems Branch became part of this new Division as the Ocean Engineering Branch. The loss of a nuclear device off the coast of Spain in early 1966 and the SCORPION tragedy in 1968 were clear examples of the need for increased effort in deep-sea inspection and recovery.

Soon after these tragedies, another Division, the Ocean Technology Division, was formed and key personnel were separated into two groups—the Ocean Engineering Branch, and the Ocean Instrumentation Branch—in order to broaden the base of support for this important work. These two groups have grown slowly and have continued their involvements in deep-sea inspection work and in developing improved equipment and techniques. In deep-sea inspection work, the most stable accomplishments are: the location and recovery of the research submersible ALVIN, the location of the lost French Submarine EURYDICE, the repeated surveys of the LEBARON RUSSELL BRIGGS hulk (used to dispose of a large quantity of nerve-agent-bearing munitions), and the inspection of munition disposal sites to ascertain possible adverse environmental effects.

One recent significant development is the light-behind-camera (LIBEC) system (see Figure 1), which has increased the practical operating range of deep-sea photography by at least a factor of two. This advance means not only that greater photographic coverage is possible, but also that towed equipment can be operated much higher above

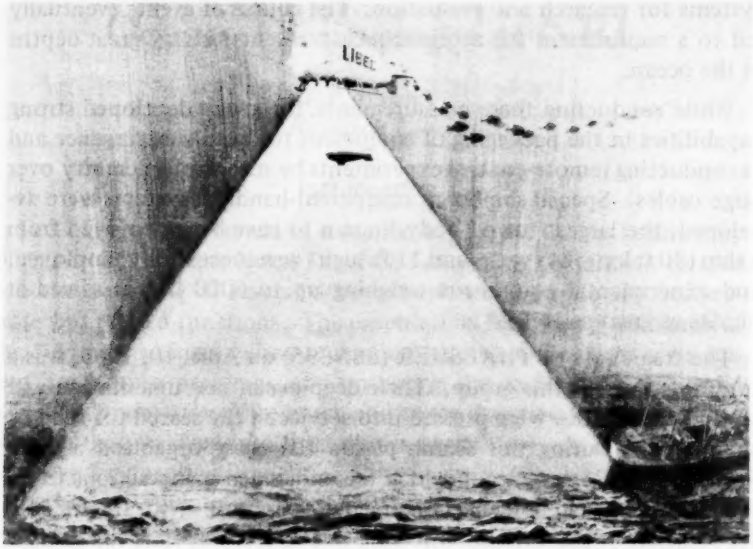

Figure 1–Extension of deep-sea photographic coverage by Light-Behind-Camera (LIBEC) system. Artist's conception illustrates lighting principle.

the ocean bottom than formerly was possible. The use of underwater photography for geological and physiographic research in areas of rough terrain is enhanced, and a forthcoming cruise will utilize LIBEC equipment in the difficult task of inspecting the floor of the mid-Atlantic Rift valley.

The growing use of underwater cable systems has stimulated a research program to study the problems in assuring a long and useful life for these systems. Past efforts have developed accurate means of measuring the significant mechanical properties of cable, thereby enabling accurate determination of the change of properties due to cable deterioration in service. Another study now under way concerns the methods of installing cable systems in the ocean and the inherent problems of varied procedures. Results of these investigations will yield better procedures for installing the best cable to provide maximum service life.

Ocean Materials Criteria

The Ocean Materials Criteria Branch (OMCB) is the post-1967 name for a technical group that had been the called Ballistics Branch and which dated from the founding of NRL in 1923. OMCB's primary charter is the application of physical mechanics and related disciplines

to problems of obtaining strength, while avoiding failure, of all sorts of solid materials.

The Ocean Materials Criteria Branch continues pioneering work on fracture mechanics, a relatively new technology which owes much to the original contributions of Dr. George R. Irwin and his staff during the 20 years following World War II. Additional emphasis is presently being put on understanding the failure of materials and on developing technology to assure reliable use of new materials for Navy purposes. The probability of practical results from this research is enhanced by cooperative work involving the analytical and experimental studies of other Branches in the Division.

The spectrum of strengths and failures, and the kinds of materials involved, has changed with the exigencies of the naval service over the years. The early years involved the development of instruments for observing the flight and impact of projectiles and torpedoes. The second decade, which eventually was accompanied by a greatly expanded wartime work force, saw intensive work on the penetration of armor plate and of light armor for aircraft and personnel protection. An interest in fabrics and ceramic armor materials emerged, and it still survives today in spite of waning postwar interest in ballistics. The armor research was replaced by a growing concern for failure by crack propagation (*i.e.*, fracture) of all sorts of materials and structures–fighter aircraft canopies, transport plane windows and pressurized transport fuselage, large electrical ac generator rotors, rocket "motor" casings, large turbojet transport landing gear, *etc.* The Branch effort resulted in a new discipline in mechanics, the Irwin linear elastic fracture mechanics (LEFM). Test methods of the LEFM have now been systematized by various technological societies and are used in DoD contracts to specify requirements for fracture toughness of critical aerospace structures. In recent years interest has shifted to the effects of the extreme naval environment (the ocean), upon fracture and other forms of material failure.

The immediate postwar years saw some important firsts, including a photoelectric version of the optical chronograph, a strain-gage-instrumented Hopkinson pressure bar, a light seismic-type pendulum to measure the air drag on a massive projectile by trapping the air thrust aside and forward as the bullet passed through, and others. Another postwar area of interest in ballistics was the defense against the looming ICBM, which required data on the missile's collision with flak. A practical laboratory gun for the projection of flak-like objects at reentry velocities, *e.g.*, to 8000 meters per second, was invented, and provided the basis for a massive NRL effort to collect needed hypervelocity impact data.

Dr. Irwin's interest in brittle fracture (Figure 2) is believed to have been kindled by his observation of battleship armor plate spalling and cracking during proof firings at Dahlgren. Among Irwin's contributions to the more basic advances of fracture mechanics, are his crack-tip stress analyses, published in 1957 in the ASME Transactions; the fracture mode transition paper published in 1960, which is basic to all fail-safe design of critical high-performance structures; and the 1962 paper which analyzed the most common structural crack defect, the elliptically shaped surface crack.

Some major applications of the developing subject of fracture mechanics at NRL should be noted. In 1951 it was demonstrated that hot stretching, followed by chilling, of transparent acrylic resin plate would toughen it. Fracture mechanics provided a method to measure the toughness of the plastic before and after chilling. This

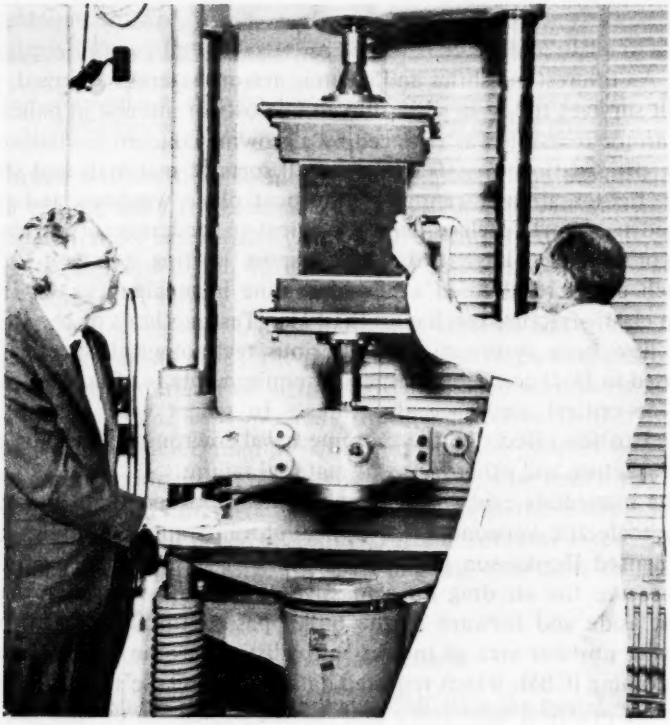

Figure 2–Preparation of a specimen under axial load for fracture test. Dr. Irwin is watching Mr. Clark in process of initiating crack in sheet specimen.

was the means then for rational guidance of commercial-scale process development and quality control. The hot stretched plastic was first used for aircraft windows in the Convair F-104, and subsequently this material became the choice for all commercial jets and several other military aircraft.

Early in the spring of 1958 it became evident that brittle failures of the motor cases of Polaris missiles constitutes a grave threat to the development schedule. A formal proposal to use fracture mechanics to help resolve this problem was presented to the Special Projects Office in April 1958. The resultant activity continued for several years, dealing with missile components from nozzles to the mylar diaphragm.

Within recent years the emphasis on materials research at NRL, and at several other Navy Laboratories, has been shifting more and more so as to anticipate and serve the focal objectives of ocean engineering programs. As presently planned, the focal projects requiring support will include those involving structures and equipment for ocean bottom operations such as geodetic surveys, salvage operations, and manned habitats providing good viewing. At present the development of the linear elastic aspects of fracture mechanics is just about exhausted by a flood of papers from universities and from industry. This leaves a considerable amount of hard work to achieve high performance and reliability in composites and in materials so plastic or tough that the linear elastic model cannot be applied. The latter case is being dealt with admirably by the fail-safe philosophy and the test methods of W. Pellini and others at NRL. There is a growing need for still higher performance hardware, however, and LEFM is not the entire answer. The research which must continue is in the difficult area outside ductile fail-safe and conventional fracture mechanics criteria.

The current Branch organization divides about 25 members into five relatively autonomous, yet closely interrelated, sections. Three of these sections deal directly with specific systems and/or uses of materials: (a) plastics and composites, (b) metallic alloys, and (c) ceramics and armor materials. Two sections deal with techniques for assessing the ingredients of material failures: (d) stress analysis, and (e) flaw detection.

Composites of glass and polymeric binders often provide a degree of resistance to degradation by sea environment and a strength-to-weight ratio far superior to that of metallic systems. The fiber-reinforced plastics such as glass-reinforced plastic, though best in tensile loading, still retain weight advantage in hydrostatic loading for uses such as submersible containers. In developing a practical

failure mechanics for such composites, problems unfamiliar in metallic alloys emerge: directionality of fiber layups, surface adherence at the fiber-plastic interface, the inherent brittleness of the constituents, the mismatch of elastic constants, the viscoelasticity character of some polymers, and thermal properties. A generalized approach to simulating the conditions for structural collapse involves the modeling of the growth of the failure zone in laminated orthotropic plates subjected to in-plane loads. Aspects of the problem being addressed include the construction of a testing system that can produce general in-plane loads on the specimen and carry out automated adaptive searches for critical energy paths to failure. A highly automated laboratory has been developed for carrying out this work.

While nonmetallic composites undergo development, many current hydrospace and aerospace projects proceed with metallic alloy systems which utilize a relatively conservative technology. Although this technology is relatively mature, important gaps remain. For example, environmentally induced subcritical cracking is highly unpredictable, and basic mechanisms even for dry fatigue-crack propagation are lacking. A satisfactory understanding of the rate sensitivity of ferrous alloys is lacking. In one approach, the role of plastic flow properties is studied in connection with various other fracture phenomena. The tensile ligament instability model has been helpful in correlating several diverse behaviors, *e.g.*, it has recently been generalized to include the case of crack propagation under repeated loadings in corrosive environment. As in all our programs, we are involved here in both the assessment of materials for new Navy programs and in the search for more fundamental reasons for the failure processes.

The provision of effective and lightweight protection for foot soldiers and helicopter personnel is a continuing and vital problem. The more practical tasks under way include: improving techniques for assessing the effectiveness of personnel armor; developing laboratory techniques for more realistic simulation of the service fragment environment; and the ballistic evaluation of new materials. The more basic studies involve the effects of structure, chemistry, and properties of materials upon penetration resistance, and the response of materials to dynamic straining. The ceramics and glasses are also studied with regard to the effects of environment on subcritical crack propagation, which is the common mode of fracture under sustained (rather than impact) loading. Expertise from the Branch's 50 years of experience in armor problems is utilized by the armed services in frequent calls for advice and consultative services.

The design of naval structures of high reliability requires the use of experimental stress analysis at each phase of the design process. An experimental stress analysis laboratory with primary emphasis on the development and application of advanced techniques is maintained. In the theory of stress analysis a new mathematical technique has been developed for analyzing stress optical systems. Although the present approach is to use a different mathematical method to derive the governing relations for each of the separate optical techniques of stress analysis, each of these techniques is actually based on the same underlying physical phenomenon. Another aspect of this research is to develop a general theory of polarization holography. A new holographic interference technique, "differential stress-holo-interferometry," was developed for photoelastic models and was verified experimentally. A new program utilizes repeated high-intensity, short-duration laser pulses to analyze the dynamic response of plastic scale models of a new naval ship design.

The tendency to brittleness in many otherwise structural materials means that small flaws may be critical. The uncertainty of nondestructive testing has long been the weak link in certification of structural integrity. Present tasks in this area include assessments of suspicious areas of service submarines, the comparison of stress wave emission with ultrasonic detection of cracks, development of test calibration devices, and the assessment of nondestructive testing (NDT) requirements for Navy missiles. A research goal is the development of pulsed laser images of the perturbation of traveling waves by flaws through schlieren photography. Another goal is the development of techniques to identify the size, shape, and orientation of imbedded flaws from spectral time phase analysis of the reflected signal.

It is a remarkable but little known fact that the traditional Navy "proof test" designed to assure the absence of critical flaws does not protect against the growth of fatigue and stress-corrosion cracks even in tough steels. Nondestructive evaluation in the light of knowledge of subcritical crack growth rates is the only hope of avoiding delayed failures.

Applied Mechanics

During the early years of NRL the work in the mechanics area helped solve many Navy problems. Basic work in thermodynamics, ballistics, magnetism, shock, vibration, elasticity, *etc.*, resulted in significant contributions. The thermal diffusion process for isotope separation evolved from World War II work at NRL. Better understanding of projectile dynamics and damage processes saved lives and

material. Improved design procedures and test facilities improved reliability of ship and missile systems subject to hostile shock and vibration environments. Basic knowledge of forces operating on both the microscopic and macroscopic scales helped explain the mechanics of fracture in materials. The inevitable realighment of work after the war years, when some personnel moved on to other organizations, resulted in emphasis on material mechanics problems as discussed in the preceding section, and on structural dynamics problems as will be discussed in this section.

The development of the atomic bomb presented an entirely new dimension to the problem of environmental loading of naval structures. When the Navy conducted its first series of underwater and near-surface bursts near Bikini atoll in 1946, NRL shock and vibration researchers were present to measure and analyze the effects on ships and submarines. These initial experiments clearly demonstrated the immense damage potential to ships from this new weapon. Since the need for further experimentation to define the environment and weapon effects was obvious, many experiments with nuclear weapons were conducted during the succeeding 10 years or so.

Operations IVY and CASTLE were two such experiments conducted in deep water to determine the free-field characteristics of the nuclear burst. Engineers from the then Mechanics Division measured the underwater pressure signature at various ranges from location. In the light of the primitive status of telemetry and remote recording equipment at that time, and the very adverse conditions in the ocean, the measurements obtained were a significant achievement.

In 1955 a combined test of the environment and weapons effects, called Operation WIGWAM, was conducted in deep-ocean Pacific waters. This test was directed to the effects of an explosion on a submarine hull and its interior components, and a number of realistic models were used. NRL scientists measured the pressure wave very near the explosion center, and much was learned regarding the response of submarine targets. It became clear, for example, that the effects on shipboard systems were similar for both nuclear and conventional underwater explosion, with certain important variations because of the immense scale differences in loading time and damage ranges involved. The results of these and similar experiments enable NRL to provide shock design motions for analytical studies of the Fleet Ballistic Missile (FBM) system, and for the TRIDENT system.

World War II developments continually lead to more sophisticated shipboard systems and antiship weapons. To ensure reliable operation, more attention to shock and vibration environments and to the design and test of equipments subjected to them was essential. Thus

the Shock and Vibration Branch and the Structures Branch (both predecessors of the Applied Mechanics Branch) became deeply involved in measurement, analysis, and test development programs. The environmental loadings were the usual and unusual ship vibrations during operations and the transients from near-miss underwater explosions and from bombs and gunfire. Measurements of these environments on board ship have continued to this time, with better instrumentation yielding more comprehensive data.

Analysis of these data, coupled with structural response theory, resulted in engineering design methods for ship shock. For example, the NRL Dynamic Design Analyses Method is now the standard method of shock-designing ship equipment. After 10 years of application, its validity has been amply demonstrated by many field experiments. And with the development of new ship types of drastically different design and materials, continued developmental research will ensure the existence of shock design capability.

In this area of research, as in most disciplines, greater confidence is properly placed in a careful test than in analytical design. The calibration of available shock facilities, the extension of their capabilities, and the development of proper test procedures gives the Navy the capability of providing more reliable shock-resistant systems. The real value of design or laboratory test procedures, however, is best demonstrated by an operational test of the improved systems. This is an integral phase of Ocean Technology Division programs. For example, the underwater explosion test series against the modern destroyer USS KNOX clearly showed the superior shock resistance of systems designed by DDAM. Other large-scale programs of underwater explosion tests against ships, such as Operation DIVE UNDER, not only provided design data for ship systems but also evaluated current design procedures. (See cover picture)

An outstanding example of a combined experimental and analytical program was that concerned with the shock resistance of nuclear power plants for Navy ships. The first prototype plants were designed in the late forties, and the need for shock resistance was recognized as a pressing problem. Mechanics Division engineers conducted an extensive set of tests in the Chesapeake Bay to evaluate the shock resistance of the two prototype reactor plant designs. Because the reactor-powered submarines were much larger than the older fleet-type boats, this program included scale models and an extensive study of shock effects. Data from these extensive tests were of direct design value in assuring a high shock resistance of the reactor plants installed in the submarines NAUTILUS and SEA WOLF. Even more important has been the long-term gain in submarine shock hardening

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resulting from this comprehensive set of data. NRL's DDAM, the scaling laws for extending results of low-severity tests, and the understanding of complex equipment-ship interaction effects are a few significant benefits from this series of shock trials.

As the knowledge from these initial tests was incorporated into newer reactor plant designs, the desirability for operational shock tests increased. Thus, in 1960-62, three at-sea shock test series were conducted against the modern nuclear submarines SKATE, SKIPJACK, and THRESHER. Each of these test series off Key West included several nearby underwater explosions which loaded the operating submarine at low to medium shock severities. Extensive on-board instrumentation of ship motions and reactor plant response was installed by NRL engineers. Other than some minor problems, such as with small appendages, the reactor plant demonstrated its anticipated shock resistance. Of more importance in the long term, these tests validated the shock design motions, the scaling laws, and the interaction effects derived from the early test series. This work has had a significant impact on ship system design by assuring desired shock resistance under near-miss underwater explosion.

Certain more basic studies have supported the comprehensive shock and vibration program. Many studies, made with the use of various types and patterns, have investigated the effect of loading rate on the elastic yield strength of usual naval construction materials. Although the increase in yield point under rapid load rates is real, NRL results have shown that this is a nebulous effect. If some form of stress raiser is present, as is usual in actual structures, the beneficial effect of increased yield point is often nullified.

During the initial days of satellite launchings, when NRL conducted the Vanguard program, the Branch did significant pioneering studies on satellite reliability under dynamic loadings. The concept of comprehensive developmental testing of components, subassemblies, assemblies, and complete payloads evolved from these studies and produced a highly reliable satellite. Much of this knowledge was carried over to a number of NASA scientific satellite programs, which have benefited from application of this comprehensive test philosophy. The development of reliable satellites designed at NRL is continuing through the use of this same test procedure.

Improved inspection methods have been developed for ensuring structure reliability. For example, an essentially nondestructive procedure for determining residual stress was evolved, including those particular hardware items necessary to expedite its use. The publication of this procedure brought a request for technical assistance from the government of Uruguay. Instructions in using the procedure, and

certain loan equipments, were provided to an Uruguayan engineer who was then able to solve a major maintenance problem of a large power-generating dam. In another area, nondestructive inspection procedures with ultrasonic waves have detected internal flaws in FBM components, thus preventing potential catastrophic failures of this important weapon system. These examples are illustrative of special-purpose efforts through which the OTD work contributes to improved reliability of Navy equipment.

Ships and submarines are not the only structures of Navy interest. Important studies of currents, tides, and weather involve quite a different structure, composed entirely of anchored cables supported by surface buoys. Such structures must operate predictably and have long life, and a powerful method has been developed for calculating their motions under wave and current loadings. Known as the Method of Imaginary Reactions, it uses an iterative process to converge on the answer. This method has received considerable recognition in the pertinent technical literature for other types of problems, as well as for underwater cable problems.

In order to provide correct loadings to underwater structures from natural environmental sources such as currents, the several forces induced during flow across submerged bodies are studied. The component forces result from the turbulent interactions caused by the presence of the body. A related study has improved understanding of the beneficial effects of polymeric coatings in reducing ship drag.

These studies again illustrate the valuable approach of comprehensive study of all aspects of a structural problem, *i.e.*, to measure the loading in the field, to analyze field data in conjunction with applicable theory so as to yield engineering design and/or test procedures, and to validate the worth of these procedures through application to operational systems, including proof tests thereof.

Division Staff Activities

The World War II experience of the military forces had shown the need for research and development in the damaging effects of shock and vibration environments. As beneficial results from these studies were obtained by specialists at NRL and elsewhere, the need for disseminating these results to design engineers became evident. In 1946-47 Dr. Elias Klein began what has grown into The Shock and Vibration Information Center (SVIC). Initially, Klein's activities included conferences and information interchange only between Navy activities. Soon Army and Air Force groups joined in the Symposia, and when NASA was formed it became the fourth sponsor of the Shock and

Vibration Coordinating Activity. Contractors to DoD and NASA, of course, were invited participants from the early days.

When DoD established official information centers in a number of technical specialties, SVIC expanded its scope as an information source. After 25 years at NRL, SVIC now serves as a worldwide center of information through its annual Symposium and Bulletin, its monographs, its Digest of technical literature, and its information bank. It is financially self-supporting to a significant degree through subscriptions and through the sale of its publications and services, with sustaining information center funds coming from DoD through the Naval Material Command.

Since its inception, SVIC has been at NRL where it has had access to the knowledge and experience of OTD researchers in shock and vibration. In 1972 SVIC was formally shifted into the Ocean Technology Division, where it continues to serve many organizations by collection, storage, and dissemination of shock and vibration technology.

Shortly after OTD was organized, a Division Consultant Staff group was formed to assist the Superintendent with special tasks and to develop new programs. Several specialists in the areas of structural dynamics, ocean engineering, and systems engineering staff this office. Special feasibility studies of underwater surveillance platforms, of lighter-than-air airships of modern design, and of large floating shock platforms have been completed. Significant studies have been performed on basic problems such as the worth of shock hardening as compared with alternate means of retaining naval power in wartime situations, and the real significance of plastic yielding in shock design. And staff members have continued consultative efforts supporting the TRIDENT program, the cruise missile program, and the underocean survey program. These staff members are self-supporting by virtue of their continuing individual research funded by various offices; they additionally provide staff support to the entire Division.

Summary

The personnel and facilities of the Ocean Technology Division are grouped so as to provide effective answers to Navy problems in several areas of engineering research. These areas include:

Material mechanics–with emphasis on predicting service lives of various metallic and nonmetallic materials in probable service conditions;

Structural mechanics–with emphasis on effects of near-miss explosions or ship vibrations on ship systems, and effects of underocean environmental loadings on flexible underwater structures; and

Ocean engineering—with emphasis on unmanned platforms and observational instrumentation to monitor the deep-ocean and ocean-bottom characteristics and properties.

In each of these areas in which OTD has long-time expertise, the comprehensive approach of measurement, analysis, design, and proof testing is followed. The Division is thus prepared to accept responsibility for all aspects of a program in its areas of competence and has demonstrated this during various successful operations in recent years.

While emphasizing the use of technology to provide answers to essential Navy problems now, the importance of continuing basic studies is also recognized. Thus at any given time about a third of the Division personnel are engaged in basic research. In the past this policy has provided a strong foundation for solving applied problems, as well as furthering overall knowledge. The combination of science and engineering is the basis for effective technology, to help solve the Navy's problems of the future.

(Continued from page 7)

and power levels to 1 kW CW for long time intervals. Direct reading digital calorimetric water loads have been developed by the NRL scientists for waveguide and radiation sources.

The facility will now allow system designers to obtain complete high power system component testing during the development phase of a satcom terminal, thus saving time and money and preventing component failure in future use of the satcom systems.

Mysterious Underwater Sound Heard on Sonar is Identified

For years, a mysterious underwater sound has repeatedly been heard by sonar operators throughout the North Atlantic. Sonarmen have called it the "A train" sound because it is a series of closely spaced clicks that resemble an elevated train coming into a station.

It has now been revealed that the sound is made by the Minke whale, a small whale which was never suspected as the source because it was thought to be a somewhat rare species. Dr. Harold Winn, a scientist at the University of Rhode Island who is studying whales' sounds and behavior under an Office of Naval Research contract, has been concentrating on the Minke whale and finally succeeded in recording its sound.

He was surprised to turn up the well known "A train" sound. Since the sound has been widely heard in the North Atlantic, it now appears that the Minke whale, which seldom reaches more than 30 feet in length, is more common than previously believed.

On the Naval Research Review

Missile Systems Indoctrination Course for Reservists on Acdutra

Three officers from the NRRC 9-21, Denver, Colorado, attended successive classes on "Missile Systems Indoctrination Course for Naval Reservists" conducted by the Technical Schools Command, Mare Island, California during 1973. The two-week course, requiring secret clearance, is designed primarily to acquaint the Naval Reservist with the capabilities of the Navy's missile systems and how they can be used to counter the current threat to the nation's security. An overview of each missile system was presented by the members of the training staff, each instructor lecturing in his own area of shipboard expertise. An exceedingly informative session was conducted on "Current Threat" which served as the foundation for the discussion of the Navy's current and future arsenal. The command has a number of operational trainer systems at its disposal which serve a dual role of on-site training for enlisted technicians (A-school) as well as for reserve officers on ACDUTRA. These trainers essentially consist of the complete weapons system including search radars, weapons direction equipment, fire control radars, and launcher with training round. The latter is facility-limited however, and simulators are used where appropriate. Students are allowed to examine all facets of the weapons system and, in some cases, allowed to operate the equipment. As the officers attended successive classes, the sizes of the classes varied, but the school is capable of handling 25 officers. The course is offered four times per year. The school does not set any technical limitations on the backgrounds of course attendees.

Seminar on Water Pollution

On January 11-13, NRRC 8-3 of College Station, in cooperation with the Texas Maritime Academy, conducted a weekend seminar on water pollution. The seminar was held in Galveston aboard the SS. Texas Clipper, which is the training ship for the Texas Maritime Academy. Approximately forty reserve officers from Texas and Louisiana attended, and all reported an enjoyable and educational experience.

Featured speakers included CAPT Fred J. Benson, Dean of Engineering, Texas A&M University, Dr. A. J. Emery, Office of Naval Research, and Mr. Merton Coloton of the Texas Water Quality Board.

Figure 1–Featured speakers Dean Fred J. Benson (L) of Texas A&M and Dr. A. J. Emery (R) of ONR.

The program included tours of the R. V. GYRE, recently commissioned oceanography vessel operated by Texas A&M, and the Texas Clipper's unique shipboard biological waste treatment plant.

Research Reservist Serves as a Health Care Consultant

The Naval School of Health Care Administration, located at Bethesda, has an ongoing research unit which keeps abreast of new developments in health services administration. Sometimes the School looks to the academic world for occasional assistance and advice. CDR David G. Warren of NRRC 6-6 was able to provide some of this assistance as a Reservist Consultant. CDR Warren is a professor in health law at the University of North Carolina at Chapel Hill and is active in advising the State government on health policy matters.

His two weeks ACDUTRA at Bethesda was particularly useful to the School since regionalization of the Navy's medical services has raised new legal issues in health care. CDR Warren was available to advise about such problems as the legal status of paramedics, constitutional considerations of medical information confidentiality, and the relationship of military medical care and civilian medical laws. He

developed materials on these topics for inclusion in the School's curriculum for the Navy's health care administrators.

Space Symposium

A symposium on the U.S. Space Program was sponsored by NRRC 6-17 of Huntsville, Alabama. Huntsville is the site of the NASA Marshall Space Flight Center (MSFC), where, under the direction of Dr. Wehrner Von Braun, the powerful Saturn Launch Vehicles for the Apollo and Skylab Programs were developed. Earlier, as part of the Army Ballistic Missile Agency, the Von Braun team was responsible for many historic firsts in exploration of space. Especially notable were the launch of the first U.S. satellite to successfully orbit the earth, putting the first man in space in the Mercury Capsule launched by a Redstone Rocket, and the first multi-manned space flights in the two-man Gemini Capsules also launched by Redstone rockets.

The prime organizer of the Space Symposium was Captain W. L. Howard, USNR-R, who is a member of NASA-MSFC Management in civilian life. The program included a series of talks by key NASA technical management personnel, a tour of the development facilities of MSFC, and a tour of Alabama Space and Rocket Center, which is the repository for actual space hardware, such as recovered Mercury, Gemini, and Apollo Capsules.

NRRC 3-9 Visits Brookhaven

Brookhaven National Laboratory, Upton, New York, one of the Atomic Energy Commission's nuclear laboratories, has designed and built a super conducting magnet for one of its major research facilities. The niobium-titanium core of the magnet has no resistance at 450°F below zero. Hence it can be disconnected from its power source. Because of the enormous power demands for a conventional magnet, this project was undertaken to reduce operating costs and demonstrate the feasibility of operating at high magnetic fields (28 kilogauss) with an air-core magnet. The magnet is part of the new Brookhaven 7-foot bubble chamber which is used as a detector in basic nuclear research. The magnet surrounds the detector and because of its extremely high magnetic field bends subatomic charged particles. Physicists can then infer the momentum of the particles from the degree of curvature of the tracks produced in the bubble chamber.

Research Notes

NRL Radar Technique Aids In Storm Detection

Captain John T. Geary, USN, Director of the Naval Research Laboratory (NRL), has announced development of a unique radar technique that promises to be of great value in sea weather observations.

Captain Geary said a team of NRL radar scientists has developed a method for remote observation of weather effects over the ocean on a real-time basis through the use of a long-range, over-the-horizon (OTH) radar system.

Using an OTH radar, know as MADRE, NRL scientists have been able to collect ocean weather data at ranges from 400 to 3,000 nautical miles from its bay shore site at Chesapeake Beach, Md. over a major portion of the North Atlantic.

Observations from such radar methods could be used by commercial and military weather observation services to warn aircraft and ships of brewing storms at sea, thus giving mariners a real-time sea condition report in time to permit changes to safe shipping routes. At the same time, its use would be invaluable in compiling daily and long-range weather forecasts.

Captain Geary explained that the importance of the technique lies in the fact that a major portion of the North Atlantic could be surveyed in as little as half an hour, and essentially upon demand. Current reporting of weather information over the ocean by conventional means is sparse and unreliable, limitations which can be overcome with the MADRE technique.

Captain Geary added that the ability to remotely determine weather conditions over a large part of the ocean in real-time is of increasing importance for improved accuracy of reporting current weather conditions and forecasting future weather.

In the NRL technique, scientists employ MADRE to determine the magnitude of the sea state and the direction and strength of surface winds. Environmental conditions which MADRE has already observed range from calm seas to hurricanes.

Unlike conventional microwave radar commonly employed for the detection of aircraft and ships, MADRE operates in the high frequency (HF) portion of the electromagnetic spectrum. (The HF region is sometimes called the shortwave band, used by radio hams for world-wide communications.)

A typical operating frequency of MADRE may be 15 megahertz, which is almost two orders of magnitude lower than the frequency of microwave radars used in the Air Traffic Control System. At these frequencies, Captain Geary explained, the radar waves are bent (refracted) by the ionosphere, which is located about 100 miles above the earth.

After refraction, the waves return to the earth at distances from 400 to 2,000 miles away, and illuminate the sea patch of interest. Some of this energy is scattered back to the radar via the ionosphere where it is received and measured.

Longer ranges than 2,000 miles are obtained via multiple refractions from the ionosphere. Hence, the HF radar uses the ionosphere to overcome the limitation of other line-of-sight radars to provide over-the-horizon information on the environment.

Captain Geary said the remote weather sensing capability of MADRE is based upon measurement of the characteristics of the radio energy reflected from a series of patches of the ocean surface. These radar signal characteristics are determined by the degree of sea surface roughness within a patch. The degree of sea surface roughness in turn has been shown by oceanographers to be related to the wind speed and direction of that area. Hence, both the sea roughness and wind characteristics can be inferred from a single radar measurement . . .thus the conditions of the sea over broad areas may be observed.

Principal science investigators for the project were Dr. Dennis Trizna, and James Headrick, of NRL's Radar Techniques Branch under the direction of Dr. Merrill Skolnik, Superintendent of NRL's Radar Division.

The development of this new long-range weather sensing technique was sponsored by the Office of Naval Research as part of the Navy's exploratory development program in radar that is carried out by the NRL Radar Division. This work represents but a portion of the program in exploration and development of over-the-horizon radar for Navy applications. Although the Navy has a direct interest in knowing the weather conditions at sea, this technique also has wide applications in the civilian sector.

Work in this area continues in progress at the NRL MADRE experimental facility at Chesapeake Beach. This radar is capable of covering the North Atlantic. Additional experiments are being planned with a new radar to cover the North Pacific in cooperation with Wave Propagation Laboratory of the National Oceanic and Atmosphere Agency (NOAA) under the leadership of Dr. Donald Barrick and the Institute for Telecommunications Sciences under the directorship of Mr. Douglas D. Crombie. These Department of Commerce organizations and the Naval Research Laboratory plan to jointly operate an over-the-horizon weather observation radar to be located on San Clemente Island and directed toward the Gulf of Alaska.

The Tasaday Expedition

The *Thomas Washington*, research vessel for Scripps Institution of Oceanography, has returned to San Diego from her 9 1/2-month, Tasaday Expedition. She was laden with core samples that may hold the key to heavy metals buried beneath the sea floor off southeast Asia.

Other scientific findings included the discovery of:

- a geologically young subduction (trench) zone east of Luzon in the Philippine sea;
- a sea-floor spreading center in the Central Basin fault that lies in a line from Taiwan to Yap in the Phillippine Sea;

- an exceptional ability to locate and devour food by certain groups of benthic (bottom) marine animals in a food-poor environment located at a depth of 6,000 m (almost 4 miles) about 400 miles north of Hawaii;
- an anomalously high rate of acoustical absorption in the Sulu Sea that appears to be inconsistent with other measurements made in the open ocean and adjusted for temperature variance.

A continuation of previous research in the Bay of Bengal (southeast of India) and in the Andaman Sea (south of Burma) confirmed previous speculation that thick sediment from the Bengal Fan, derived from continental India prior to its collision with southern Asia, is being scraped off the underthrusting sea floor and folded into the Indo-Burman ranges, the Andaman and Nicobar Islands, and the islands off the coast of Sumatra.

Tasaday research consisted of a wide variety of biological, ecological, and geophysical investigations conducted by scientists from the United States and Japan on board the *Washington* during her 44,500-mile expedition to the western Pacific and eastern Indian Oceans.

Robert C. Newbegin was cruise captain for the first five legs of Tasaday. John W. Bonham relieved Newbegin on October 7, 1973, and captained the 1,302-ton, 209-foot vessel for the remaining five legs.

Dr. Roger N. Anderson was cruise coordinator and chief scientist for one leg of the expedition. Other chief or co-chief scientists were: Scripp's Dr. John R. Beers, Dr. Hugo F. Bezdek, Dr. John A. McGowan, Dr. Joseph R. Curray, Dr. David G. Moore, Dr. Michael C. Gregg, and graduate students Peter Jumars and Eric Shulenberger; Cornell University's Dr. Daniel E. Karig, and the University of Washington's Dr. Bruce A. Taft.

Tasaday's multi-disciplinary oceanographic expedition, funded by the National Science Foundation and the Office of Naval Research, included water microstructure measurements off the California coast and in the central North Pacific Gyre (closed circulatory system); biology of the central North Pacific Gyre; physical oceanography of the Kuroshio Current off Japan; and geological and geophysical studies of the interarc basins of the western Pacific and the Bengal Fan in the eastern Indian Ocean.

From January 22 to February 17, 1974, the *Washington* was diverted from Tasaday for work with Scripp's FLIP (Floating Instrument Platform) on the North Pacific Experiment's (NORPAX) POLE project in the north central Pacific in a 200-mile-square area near Hawaii. POLE was a field experiment largely devoted toward describing the intense wintertime interactions of the ocean and the atmosphere in enough detail to permit plans for later experiments with large coverage of the ocean.

Dr. Anderson conducted geophysical research in the Marina Trough northwest of Guam. Recovered cores are hoped to yield evidence of heavy metal deposits in that area. Expectations are based on high heat flow and high sediment temperatures that suggest that heavy metals may be leached from the rocks and precipitated in the sediments as sea water percolates through the rocks.

Conditions of heavy sedimentation in the trough combined with the high temperatures may accelerate the "cooking" of sediment and eventually yield oil.

This area can be compared to what the California borderland basins, such as the Santa Barbara basin, may have been like about 10 million years ago.

Studies by Dr. Karig included nearly continuous reflection, magnetic and bathymetric profiling while en route from Yokohama to Singapore through the Philippine Sea. His research yielded two findings. Surveying, dredging and coring east of Luzon substantiated that a geologically young subduction zone (trench) is developing along this margin. The crew captured a trench in the process of being formed. Dr. Karig also conducted a detailed survey of the Central Basin fault, which lies in a line from Taiwan to Yap, and determined that it is a spreading center.

Other research by Dr. Karig included work at three seismic refraction stations: one for a survey with the assistance of the R/V *Bosai Maru*, a Japanese vessel, in the Shikoku Basin to investigate non-uniform properties in the earth's mantle; the other two for one-ship sonobuoy (listening devices) profiles in the West Philippine Basin.

While measuring acoustic absorption in the Sulu Sea (between Sabah, Malaysia, and the Philippines), Dr. Bezdek's readings were anomalously high, and appear to be inconsistent with measurements made in the open ocean and adjusted for temperature variance. The Sulu Sea is a "closed system" with no interaction with adjacent water bodies. The water temperature is "unique" in this area in that it is extremely warm (about 10.5°C) to a depth of 4 km (more than 2 miles) as compared with an open ocean temperature average (about 1.5°C). Dr. Bezdek thought the reasons for this acoustic absorption inconsistency is a question that remains to be answered. Sometimes you get answers, and other times you get questions.

Geological and geophysical evaluations of the Andaman Sea and Bay of Bengal by Drs. Curray and Moore confirmed that thick sediment from the Bengal Fan was being scraped off and folded into the Indo-Burman ranges, the Andaman and Nicobar Islands, and the islands off the coast of Sumatra, as the sea floor moves to the northeast and plunges beneath the thin sedimentary arc.

Previous geophysical work in the Bay of Bengal had shown that the sediment column exceeds 16 km (more than 10 miles) in thickness at the northern end of the bay, one of the thickest sediment sections in the world. During Tasaday, work was continued farther to the southwest in the Bay of Bengal to delineate thicker parts of the sediment column for purposes of relating to geological history. Much of that sediment was derived from continental India prior to its collision with southern Asia.

Since collision of the Indian continent with Asia in early Tertiary time (about 55 million years ago), some of the thick sediment column has been scraped and folded into the Indo-Burman ranges, the Andaman and Nicobar Islands, and the islands off the coast of Sumatra. These regions of deformed sediment were investigated by Drs. Curray and Moore to attempt to evaluate the process of scraping of a thick column of sediment from a subducting or downgoing plate, and thrusting and uplifting into a mountain range.

Under the direction of Dr. Taft, the flow of the Kuroshio Current over the Izu-Ogasawara Ridge was studied by means of free-vehicle current meters, expend-

able bathythermographs (XBT), STDs (salinity, temperature, density measuring devices) and drogues.

The ridge presents a major topographic obstacle to the flow of the Kuroshio, and by tracking selected isotherms (a line on a map connecting points having the same temperature at a given time) the current's path over the ridge can be determined. The main focus of the work was on the interaction of the deep flow of the Kuroshio with the ridge. During the work the position of the surface Kuroshio was monitored by means of XBT drops. The density field in the vicinity of the ridge was determined from STD observations and will be used to compute the geostrophic (deflective force due to the rotation of the earth) flow field.

Drogue measurements gave an indication of the surface current distribution and the relationship between the current and subsurface temperature distribution. On 15 stations concentrations of phosphate, silicate, and oxygen were determined and will be used to trace the pattern of the deep flow through the ridge and around it.

Two legs of Tasaday had as their dual purpose the investigation of the temperature and salinity microstructure of the water column, and study of the various aspects of the biological energy flow, nutrient cycling, and plankton in the central gyral region of the North Pacific, although considerable work was also accomplished at the western edge of the California Current.

Drs. Beers and McGowan of Scripp's Food Chain Research Group (FCRG) and Marine Life Research Group (MLRG), respectively, conducted studies on the plankton food-chain dynamics in the central gyral region of the North Pacific, an area with relatively orderly and predictable plankton population structure.

Principles that result from the quantitative description of the pelagic ecosystem in an orderly environment such as the gyre will be important aids in developing an understanding of highly complex and less predictable systems such as found, for example, in the California Current.

Dr. Beers's work was done in June and July, and Dr. McGowan's investigations were in February and March for seasonal comparison. These were parts of an extensive program that includes several earlier cruises to the gyral region.

In addition to a basic set of measurements and sample collections that will provide information on seasonal and annual differences, a wide variety of special biological studies were conducted, including the use of free-vehicle traps to obtain abyssal (deep-water) amphipods (a type of crustacean), the rearing of predaceous copepods for the purpose of determining their life cycle, the study of micro-zooplankton populations in waters below the depth to which light sufficient for algal plank production penetrates, and studies of nekton (animals with relatively well-developed swimming capacity, including small fish).

Investigation of the temperature and salinity microstructure of the water column was under the direction of Dr. Gregg. Observations were directed at comparing the yearly changes in the heat content of the upper 1 km to the centimeter scale temperature fluctuations from data records. An understanding of the physical mixing processes on these small scales is necessary before oceanographers can fully detail the heat and salt budgets of the oceans. Such information can, in turn, be used to predict the dispersal of pollutants introduced into the oceans.

Two Scripps graduate students were chief scientists during the expedition. Eric Shulenberger's work was an extension and broadening of the ongoing Central Gyre biological studies being conducted by Dr. McGowan's group. His work was focused on the eastern half of the northern gyre to help elucidate whether the gyre is indeed one coherent community of marine organisms, or perhaps two subtly different communities. Shulenberger conducted a biologically-oriented transect across the Central Gyre. Hydro stations, with attendant chlorophyll, nutrient, salinity, and oxygen analyses, and large-volume plankton tows were taken. Special studies in geology, physical oceanography, neuston (surface) tows, and phycology (samples and cultures) were also accomplished.

Graduate student Peter Jumars coordinated continuing investigations by Scripps's Dr. Robert R. Hessler of the deep-sea-bottom, community structure in unproductive regions of the Central Gyre. About 400 miles north of Hawaii, Jumars found with the aid of baited traps that in that food-poor environment, where most animals are less than a quarter of an inch long, a number of very large animals, especially fish, and a group closely related to sand fleas, had exceptional ability in the locating and devouring of food.

Expedition Tasaday was named for the Stone Age cave dwellers recently discovered in the Mindanao rain forest of the Philippines, said Dr. Anderson. "We had hoped that our expedition would be as successful in exploration and discovery in the oceans as the Tasadays were in escaping civilization for so many years. Although it will take time for all of the data to come in, preliminary results were gratifying."

New Photos of The Floor

– Ocean scientists at the Naval Research Laboratory (NRL) have obtained more than 5000 photographs of the sea floor inside the median Rift Valley of the Mid-Atlantic Ridge with NRL's LIght BEhind Camera (LIBEC) system.

The LIBEC concept permits photographs of the deep ocean bottom to be taken at greater ranges than heretofore possible. This is achieved by separating the camera from the zone of intense backscatter near the light source while directing most of the light energy towards the outer edges of the target area.

LIBEC is deployed from NRL's research vessel MIZAR through the ship's center well, and towed by means of a cable-telemetry system, which has enhanced the Navy's deep search capability.

Although the majority of the photos corroborate previous information that the Rift Valley is floored with pillow lava, others revealed a wealth of additional detail. Many steep scraps and fissures were seen, some of which were correlated over distances up to two miles. Further studies are planned to determine if these structures are related to volcanic or tectronic processes.

Steep rock surfaces were found to harbor a variety of sessile animals, while deposit feeders were noted in zones where pelagic sediments had accumulated. More active creatures were present in a number of exposures, and at least two photographs were taken of the rare cirrate octopod (umbrella octopus).

During the Rift Valley tests, temperature was monitored continuously and water samples were collected along each photographic run. Measurements of certain micro-constituents in the water are planned by NRL to determine recent volcanic activity.

The mission was completed in cooperation with the Woods Hole Oceanographic Institution and under the auspices of the National Science Foundation, as part of the French-American Mid-Ocean Undersea Study (FAMOUS). FAMOUS is the most comprehensive study of the Mid-Atlantic Ridge ever attempted. The Naval Intelligence Support Center has been tasked with assembling the NRL photographs into a photo-mosaic map.

The ridge is part of an undersea mountain range that is the most extensive surface feature on earth; a great suture where the continents joined 200 million years ago.

NRL investigators say it is now generally accepted that in the center of this suture, in the median Rift Valley, new crustal material periodically wells up as molten rock to congeal along the edges of massive plates. The plates spread outward from the ridge transporting sea floor and adjacent continents at a currently-measured average rate of 1.3 centimeters per year.

Energy Spectacular

Last August 21, the SKYLAB astronauts acquired a series of photographs of a large eruption of the sun's atmosphere. To obtain these unique pictures, they used a special instrument known as a spectroheliograph, devised by scientists of the Naval Research Laboratory.

This color isophote (picture) was electronically processed from the original black and white photograph taken in the light of ionized helium by the NRL instrument.

The clouds of helium gas blasted out some 350,000 miles and, eventually, streamed outward at least 200,000 miles more. (That's a top speed of more than 3,800 miles-a-minute!)

While such eruptions of the sun may be common, the ultraviolet light of helium is totally absorbed by the earth's own atmosphere. Thus, such pictures can only be made from space. It has been only in the last few years that space technology has enabled man to fly long missions with photographic instruments sensitive enough to record these massive explosions for further study and analysis.

The temperatures of the churning gases at the sun's surface are about 4,000 degrees centigrade; but they increase rapidly to about 500,000 degrees in the chromosphere, and up to some 3-million degrees in the corona.

When the energy of such a solar explosion heads toward the earth (taking several days to reach us), it can produce so-called geomagnetic storms that may disrupt broadcast communications and even common power transmission lines, and cause navigational instruments to go haywire. Such storms also cause the spectacular and well-known aurora borealis, or Northern Lights.

Theoretically, if it were possible to harness the energy of this eruption it would have been enough to provide for all of mankind's power needs from the year 1 A.D. to the present. . .and perhaps for the next two thousand years.

Research Brings Color Judgement to Color Blind

Drs. Herbert Rosenstock and David Swick, two scientists at the Naval Research Laboratory (NRL), say they have a simple device that allows the color blind to distinguish colors with little effort or training.

It consists of a set of three filters embedded in eyeglass lenses for one eye or both; red, green and transparent (for red-green color blindness). And since these filters absorb different-colored sources differentially, the viewer observes a sudden change in intensity as he moves, by a slight motion of his neck, a different filter into the path of light.

For "normal" observers, the intensity change is accompanied by a color change, and thus is of little interest. But for a color blind observer, the intensity change is sufficient to identify the color of the source.

In most cases and with properly designed filters, the intensity change is not slight or hard to observe. It is instead obvious and dramatic.

The NRL filters provide color information to the color blind by converting color differences into intensity differences, which is believed to be what the retina does for the normally sighted.

It is generally believed that the sensation of vision is initiated by the absorption of a portion of light by a pigment in one of the receptor cells ("cones") in the retina; the absorbed energy is converted by the receptor into an electrical impulse which is transmitted to the brain by the optic nerve.

Normal ability to distinguish colors results from the presence of not just one kind of receptor, but of different receptors containing different pigments with different absorption properties. Color blindness results when one of the retinal pigments is abnormal or absent.

Rosenstock and Swick believe that distinguishing emitted colored signal lights in the fields of automotive, aerospace, and marine transportation may be the most important use of their filter/lens. However, the same device also works for reflected light in distinguishing such items as color coded circuit components.

High Performance Signal Processor Computer

A very high performance programmable digital computer as a signal processor has been designed and constructed by Naval Research Laboratory (NRL) scientists.

The functional specifications of the NRL Signal Processing Element (SPE) have been incorporated in a prototype model, designated AN/UYK-17 (XB-1), built at the Laboratory and engineered to have low life-cycle costs.

Signal processing is favored in military systems because the digital domain permits maintainability, stability, and reproducibility not afforded by the analog domain.

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Until now, designers of such systems have had to choose between incorporating a standard military computer with marginal signal processing performance or developing a special-purpose hard-wired digital processor with all the inflexibilities, costs and risks attending this approach.

The Laboratory's SPE Microprogrammed Control Unit (MCU) is a high-speed, user-microprogrammable, executive input/output processor and interrupt handler for the SPE Signal Processing Arithmetic Unit (SPAU). The SPE is being used for the development and evaluation of signal processing algorithms and signal processor architectures.

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